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(54) APPARATUS FOR COMPARING REFRACTIVE INDICES

(71) We, KODAK LIMITED, a Company registered under the law of England, of Kodak House, Station Road, Hemel Hempstead, Hertfordshire, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for comparing refractive indices.

According to the present invention there is provided a method of comparing the refractive indices of two media, which comprises illuminating plane-parallel faced cells of the media, disposed with their faces in parallel alignment, obliquely with an array of elongated light beams formed by interposing a coarse grating (as herein defined) between a light source and the cells, with at least some of the lines of the grating extending over the faces of both cells, so that adjacent portions of the array are displaced to extents dependent on the refractions of the cells, causing said portions to generate moiré patterns either by reflecting the portions back through the respective cells and the grating or by positioning a second coarse grating (as herein-defined) beyond the cells with its lines parallel to those of the first grating, and observing or measuring the relative phase of the moiré patterns.

Also provided in accordance with the invention is apparatus for comparing the refractive indices of two media, which comprises means including a light source for producing a beam of light, means for supporting plane-parallel faced cells of the media with their faces in parallel alignment obliquely in the beam of light, a coarse grating (as herein defined) disposed in the beam of light so that the cells, when so supported, are illuminated by an array of elongated light beams at least some of which extend over the faces of both cells, means whereby when the apparatus is in use, the portions of said array refracted by the cells are caused to generate moiré patterns, said means being either a mirror which reflects the portions back through the respective cells and the grating or a second coarse grating (as herein defined), and means whereby the relative phase of the two moiré patterns can be observed or measured.

Apparatus of the invention may be simply constructed with no moving parts, and is particularly suitable for detecting changes in composition of a flow of a liquid.

The term "coarse grating" is used herein to refer to a planar parallel line grating which has a sufficiently low line frequency for it to produce negligible diffraction effects. The preferred line frequency is in the range 10 to 100 per centimetre.

Apparatus according to the invention is based upon the principle that a light ray is laterally displaced if passed obliquely through a parallel sided refracting medium. Consequently if parallel sided refracting media of different optical path length (i.e. different thickness and/or refractive index) are interposed, in parallel alignment, obliquely in an array of narrow elongated light beams, such as can be produced by positioning a coarse grating in a beam of light, then the emergent portions of the beams are laterally displaced to different extents. If the emergent portions of the beams then fall on a second grating (or are reflected back through the original grating), they form parallel line moiré patterns of the same periodicity which are relatively shifted. The extent of the shifts gives an indication of the differences in optical path length.

Various optical arrangements can be adopted in apparatus of the invention. Thus it is possible either to use a slightly convergent or divergent light beam with two gratings having the same line spacing, or to use a parallel light beam with gratings of slightly different line spacing. If it is desired to obtain a brightness difference between the integrated light beams emerging from the two liquids then a parallel light beam can be used with gratings of equal spacing. This may be considered as generating portions of a single line moiré pattern.

The plane of the coarse grating used for forming the array of elongated light beams need not be parallel to the cell faces. In fact the orientation of the grating can be adjusted to alter the frequency of the moiré patterns obtained.

Apparatus of the invention is very suitable for comparing the refractive indices of liquids. In a preferred form of apparatus for this purpose, the cells are optically identical. It is particularly preferred for the two cells to be compartments of a single divided cell since this obviates the need for accurate alignment of separate cells. The use of a divided cell also simplifies observation or measurement of the two sets of moiré fringes by causing them to be produced close together.

If changes in the refractive index of a solution are to be observed or measured, the comparison cell may conveniently be either an optically identical cell containing a reference solution, or a parallel-sided slab of a transparent solid the thickness and refractive index of which are chosen to give a suitable shift of the moiré pattern.

Whilst it is usually more convenient to use two parallel line gratings, one on each side of the optical cells, this is not essential; the alternative arrangement in which a mirror is placed behind the cells has the advantage of doubling the optical path length and hence the sensitivity.

For apparatus designed to produce a moiré pattern of several parallel lines for each liquid it can be shown for the case where a divided cell is used with two gratings that:

$$\frac{1}{fm} = \frac{t \sin i}{\cos^3 r}\left(\frac{1}{n} - \frac{1}{n'}\right)$$

where i is the angle of incidence, r is the angle of refraction, t is the thickness of the cell in millimetres, n and n′ are the refrective indices of the liquids being compared, f is the ruling frequency in lines per millimetre and 1/m is the shift between the two moiré fringe patterns expressed as a fraction of a phase. 1/fm is the difference between the lateral displacements of the beams of light refracted by the two liquids (see Figure 2).

Any convenient optical system can be used for producing the parallel, or almost parallel, beam of light. Use of a line source allows a brighter moiré pattern to be obtained.

The moiré pattern can be observed either by allowing light beams emerging from the apparatus to fall on a screen (which may incorporate the second grating) or by looking through the apparatus towards the light source. Alternatively, the moiré patterns can be compared by photoelectric measuring apparatus.

Apparatus of the invention is readily constructed for monitoring the refractive index of a flow of liquid, it merely being necessary to provide an inlet and outlet at least for one cell. The apparatus therefore provides a convenient means for detecting changes in composition of a liquid being used in some manufacturing process; for example the degree of exhaustion of a photographic fixing solution may be followed by determining its change in refractive index. A sodium thiosulphate fixing bath containing 5 grams per litre of dissolved silver has a refractive index approximately 0.001 unit greater than that of the unused solution.

The invention will now be described with reference to the drawings accompanying the Provisional Specification in which:

Figure 1 is a diagrammatic perspective view of preferred apparatus according to the invention embodying two gratings, and

Figure 2 is a plan view of part of the apparatus of Figure 1 and shows the path of a light beam therethrough.

As shown in Figure 1, a parallel-wall optical cell (1) is divided by a partition into upper and lower parts and is disposed between two gratings (2) and (3). Each grating consists of opaque parallel lines carried by a flat transparent support. The gratings (2) and (3) are aligned with their planes parallel to each other and to the faces of the cell (1), and also with their lines parallel. The cell (1) and gratings (2 and 3) are placed in a slightly divergent beam of light produced by a light source (4) and a lens (5), and are inclined at an angle of 45° to the axis of this beam.

The first grating (2) produces a set of slightly divergent vertically elongated narrow beams of light which interact with the second grating (3) to form a parallel line moiré pattern which is observed on a screen (6). If a liquid is put into part of the cell, each narrow beam of light is displaced laterally as shown in Figure 2 so that the moiré pattern is laterally displaced also. When, therefore, liquids of different refractive index are put in the two parts of the cell, the moiré patterns are shifted to different extents so that there is a phase difference between them.

Using a 7 mm cell, 25 line per millimetre gratings and a 130 cm distance between the cell and the screen, a 3× normal aqueous potassium chloride solution at 20°C. gave a line shift, relative to the pattern for water of 1.0 cm, equivalent to 1/3 phase (i.e. m=3). From the formula above using a value of 1.333 for the refractive index of water this corresponds to a refractive index for the solution of 1.36. This is the accepted value.

WHAT WE CLAIM IS:—

1. A method of comparing the refractive indices of two media, which comprises illuminating plane-parallel faced cells of the media, disposed with their faces in parallel alignment, obliquely with an array of elongated light beams formed by interposing a

coarse grating (as hereinbefore defined) between a light source and the cells, with at least some of the lines of the grating extending over the faces of both cells, so that adjacent portions of the array are displaced to extents dependent on the refractions of the cells, causing said portions to generate moiré patterns either by reflecting the portions back through the respective cells and the grating or by positioning a second coarse grating (as hereinbefore defined) beyond the cells with its line parallel to those of the first grating, and observing or measuring the relative phase of the moiré patterns.

2. A method according to claim 1 for comparing the refractive index of liquid in a flow thereof with the refractive index of a reference liquid or transparent solid, wherein at least part of the flow of liquid is passed through one of the cells and the other contains the reference liquid or is formed of the reference solid.

3. Apparatus for comparing the refractive indices of two media, which comprises means including a light source for producing a beam of light, means for supporting plane-parallel faced cells of the media with their faces in parallel alignment obliquely in the beam of light, a coarse grating (as hereinbefore defined) disposed in the beam of light so that the cells, when so supported, are illuminated by an array of elongated light beams at least some of which extend over the faces of both cells, means whereby when the apparatus is in use, the portions of said array refracted by the cells are caused to generate moiré patterns, said means being either a mirror which reflects the portions back through the respective cells and the grating or a second coarse grating (as hereinbefore defined) with its lines parallel to those of the first grating, and means whereby the relative phase of the two moiré patterns can be observed or measured.

4. Apparatus according to claim 3 wherein the two cells are constituted by compartments of a single, divided, cell.

5. Apparatus according to claim 3 or 4 for monitoring the refractive index of a flow of liquid, having means for passing at least part of said flow through one of the cells, the other cell containing a reference liquid or being formed of a transparent reference solid.

6. Apparatus for comparing refractive indices substantially as described herein with reference to and as shown in Figure 1 of the drawings accompanying the Provisional Specification.

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PROVISIONAL SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale

Figure 1

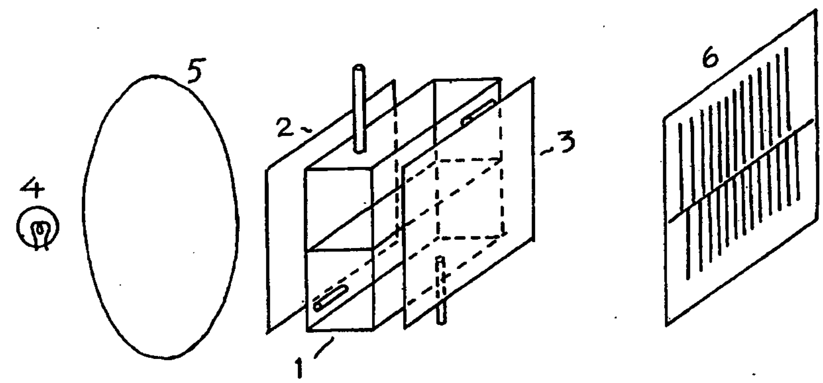

Figure 2